SUMMARY OF FOLIAR ASSESSMENT SURVEYS FOR OXIDANT INJURY TO FIELD CROPS IN SOUTHERN ONTARIO

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EXECUTIVE SUMMARY

Assessment surveys for ozone injury to field crops have been conducted by MOE Phytotoxicology staff annually since 1971 to determine the degree and extent of injury each year to sensitive crops across southern Ontario. This report summarizes the results of surveys from 1983 through 1990.

From 1983 to 1990, foliar inspections for ozone injury were conducted annually on white beans (except 1988 & 1989), tomatoes and potatoes, all of which are known to be sensitive to ozone. The regular surveys were conducted in August on white beans and in July on tomatoes and potatoes. Variety trial plots at experimental stations were examined each year, as were commercial and garden plantings during 1983 and 1984. The observations since 1985 have been primarily confined to experimental stations. In July of 1983 and 1984, several other locations/crops (primarily vegetables) also were inspected for ozone injury, including commercial fields in the primary organic soil areas. In addition, a special survey was conducted in late June of 1983 because elevated ambient ozone levels were encountered earlier in June. In 1984, 1985 and 1986, tomato, potato and/or Bel W3 tobacco plants, also were examined at a few stations in August.

Every year, during the regular survey, ozone injury was observed on the foliage of white bean, tomato and potato crops at several locations. The most severe injury generally was observed in August on white bean crops which, each year, exhibited injury ranging from trace to severe. The injury overall to white beans was severe in 1984 and 1990, as was found to be the case in only one other year (1976) since the survey began in 1971. In most years since 1971, the severity of ozone injury to white beans has been light or moderate overall. In addition, ozone injury to tomatoes and potatoes was found to be slightly increased in recent years (1987, 1989 and/or 1990) compared to other years since 1983. In spite of this slight increase, the severity of ozone injury to tomato and potato plantings in July across southern Ontario was found to be very light overall during 1983 to 1990, as in most previous years.

In July of 1983 and/or 1984, ozone injury also was observed on a few sensitive plantings of snapbean, soybean, celery, grape, lettuce, onion, radish and/or tobacco. In all of these cases, the foliar injury severity was trace or very light.

During the special survey in June of 1983, the severity of ozone injury to sensitive field crops across southern Ontario also was found to be very light.

In the years (1984-1986) during which tomato, potato and/or Bel W3 tobacco plants were inspected in both July and August, the injury was generally highest in August. The most severe injury observed during these years was on sensitive potato and Bel W3 tobacco plants and was light or moderate in severity.

The annual survey results for 1983 to 1990, together with the histological results and ambient ozone data, show that the ambient ozone levels which were encountered during the growing season each year injured sensitive field crops in southern Ontario.

Summary of Foliar Assessment Surveys For
Oxidant Injury To Field Crops in Southern Ontario
1983-1990

A: INTRODUCTION

Ozone has long been recognized as the major component of the photochemical oxidant complex and as one of the most damaging of all air pollutants affecting vegetation. Ozone is commonly associated with urban atmospheres due to precursor pollutants in these areas. However, its presence is now known to extend into rural and uninhabited areas as a result of long range transport by regional air movements. In southern Ontario, high ozone levels are generally associated with regional southerly air flows which are carried across the lower Great Lakes after having passed over numerous urban and industrialized areas of the United States. Contributing to this influx pattern are the localized, domestic downwind urban effects which can add to the already high background levels.

In an effort to assess and compare the annual severity of foliar ozone injury on sensitive Ontario crops (e.g. white beans, tomatoes, potatoes), personnel of the Phytotoxicology Section have conducted visual assessment surveys throughout the major production areas in southern Ontario since 1971. The results of the earlier (1971-1982) surveys have been discussed in a previous report (ARB-89-83-Phyto) and are briefly summarized in Appendix 1. This report summarizes the results of the more recent surveys from 1983 through 1990. The extent of the assessment coverage and the crops and number of varieties examined each year are shown in Table 11.

B: SURVEYS Of WHITE BEAN

a) Background

Bronzing of the foliage of white beans has been observed in Ontario since 1918 and was originally classed as a non-parasitic disease and referred to as sunscald. However, it was not until 1968, following extensive field work in 1965 and 1967, when the bronzing disorder was more thoroughly documented and was found to be associated with elevated levels of atmospheric ozone. The bronzing of foliage develops in the period between flowering and normal senescence, with older leaves becoming senescent and abscising prematurely. Younger, fully expanded leaves develop a bronze/black coloured necrotic stipple on the upper surface .

Since 1971, white bean crops in the major production areas of Ontario have been annually inspected for ozone injury by Phytotoxicology staff, with the exception of 1988 and 1989.

b) Methods

During recent years (1983-1990), white beans were inspected for ozone injury in late August, primarily in the variety trials at the Harrow (CDA - Canada Dept. of Agr.), Ridgetown (OMAF - Ontario Ministry of Agr. and Food), Centralia/Huron Park (OMAF) and Elora (University of Guelph) experimental stations. OMAF white

bean trials also were examined at Kippen and/or Brussels during 1984 to 1987. Also, in 1983 and 1984, commercial white bean plantings were examined at some locations. Figure 1 illustrates the general locations of field crop inspections from 1983 to 1990.

At the experimental stations, foliage was inspected on numerous varieties, including recommended varieties for Ontario. Plants in each variety plot examined were evaluated for foliar ozone damage and a numerical injury rating (from 0 to 6) was assigned which represented the average severity of injury to the plot. As plant sensitivity to ozone is largely influenced by stage of development, plant maturity also was evaluated and was assigned a numerical rating from 1 to 7. Described below are the categories for assessing foliar injury and plant maturity.

INJURY SEVERITY

Rating	Criteria
0	No oxidant symptoms observed
1	Scattered stippling on a few of the oldest leaves
2	Scattered stippling over most of the leaves
3	Moderate stippling or bronzing over a few of the leaves
4	Moderate stippling or bronzing over most of the leaves with some coalescence into flecks
5	Severe stippling or bronzing coalescing into necrotic flecks on many of the leaves; some premature leaf senescence and initial defoliation
6	Severe stippling or bronzing and coalescence on almost all leaves; plants prematurely senescent and defoliation occurring

STAGE OF PLANT DEVELOPMENT

Stage	Description
1	Plant foliage completely green; most pods are quite thin with beginning of bean development; flowers still evident and numerous 1-2 cm developing pods
2	Plant foliage completely green; most pods are quite thin with initial stage of bean development; no flowers remaining but still numerous immature pods (no beans)
3	Plant foliage mostly green with some gradual chlorotic development, pods are green with oldest ones almost to full size; youngest pods have bean formation but are still quite thin

4	Plant foliage approximately 50% chlorotic; older pods are starting to turn yellow; youngest pods still green but have beans that are approximately 50% developed
5	Most leaves appear chlorotic with only a green hue to the plants; most pods have turned yellow and have indented between the beans; still some fully developed green pods at the top
6	Leaves beginning to abscise - mostly yellow; pods mostly yellow in colour and leathery in texture; bean development mostly complete but beans still with 20-30% moisture
7	Leaves have almost totally abscised; pods yellow and dry with completely dry and mature beans (pods rattle when shaken)

The six injury rating levels previously described fall into four injury severity categories: trace (rating 1), light (ratings 2-3), moderate (rating 4) and severe (ratings 5-6). In order to compare the overall severity of ozone bronzing/stippling on white beans between locations and years, an injury severity index was devised. For each location/year, the total number of injury ratings (observations) was tallied and the percentage of ratings in each injury category (trace, light etc.) was calculated. The percentage values (decimal) were then multiplied by a corresponding weighting factor which was allocated to each of the injury categories - trace: 5; light: 10; moderate: 50; and severe: 100. Then, the separate indices were added to generate a total injury severity index score for each location (Table 1) and year (Table 2). The greater the index score, the higher are the number of ratings in the higher injury categories. A total score between 1 and < 20 is classed as trace; between 20 and 35 light; and between 36 and 50 moderate. A score of greater than 50 is classed as severe.

c) Results

In most years, foliage of white bean plantings exhibited bronzing/stippling injury ranging from trace to severe in August at most locations. Tables 3 and Table 4 show that ozone injury was particularly severe in 1984 and 1990, relative to other years since 1971. Table 4 shows that, since 1971, 1976 was the only other year with a severe injury index value. The high scores in 1984 (65) and 1990 (62) were comparable to the high score in 1976 (64). In most other years, the severity of ozone injury to white bean crops was light to moderate overall.

Statistical analyses were performed on the 1986 and 1987 injury and maturity ratings for the 16 varieties recommended for Ontario in 1989/1990. These varieties were Centralia, Crestwood, Dresden, Ex Rico 23, Fleetside, Harofleet, Harokent, Kentwood, Midland, Mitchell, Rocket, Stinger, Suncrest, Wesland, OAC Seaforth, OAC Rico. The coefficient of correlation for the combined data (all areas) showed a good correlation between injury and plant maturity, with the r value of 0.68 being highly significant ($p < 0.01$). In addition, Duncan's Multiple Range Test was performed to determine if there was any difference in injury between areas and varieties. The Analysis of Variance results in Table 5 show that, in recent years (1985-1990), there was significant difference in injury between locations. Statistical analysis of the 1990 data also showed some varietal difference. OAC Seaforth exhibited the most severe injury, while the least injury was observed on Crestwood, Fleetwood and OAC Rico.

During the regular survey in 1983, three commercial white bean plantings were inspected in the Alliston area (see Figure 1). Only one of these plantings was affected, with the severity of bronzing/stippling given an injury rating of 4. In 1984, commercial white bean plantings were found to be injured near Kerwood (injury rating 5), Parkhill (5), Exeter (4), Atwood (5), Teviotville (5), Cookstown (5,1), Bowmanville (0) and Darlington (1) (see Figure 1). The injury to these plantings (shown in parenthesis) mostly fell within the moderate or severe categories and was within the severity range found at other locations.

C: SURVEYS ON TOMATO

a) Background

Tomato plantings have been assessed for oxidant injury on a regular annual basis since 1972. The investigation began in Ontario following the report of unusual symptoms to commercial tomato crops in southwest Ontario in 1972. The injury was noticed by field representatives from the research division of a major canning company and samples were submitted to the Department of Plant Pathology, University of Guelph. After ruling out any disease problems, the Phytotoxicology Section was notified and field investigations/surveys followed. The symptomology was found to be typical of reports of PAN (peroxyacetyl nitrate) injury in the literature and has been called PAN-type injury in previous reports. To explore the cause of the injury, a number of field and laboratory experiments, using an anti-ozonant chemical protective spray, were conducted during 1978 through 1981 by Phytotoxicology personnel. From the results of this work, it was concluded that the injury was caused by ozone rather than PAN.

Ozone injury on tomatoes occurs mainly on the lower leaf surfaces. The injury is characterized by bronze, copper or grey-coloured lesions which are usually small and circular. The injury also can have a glazed/glassy appearance. The lesions can coalesce and become bifacial, resulting in larger spots of irregular shape and size on both surfaces. The injury may be scattered across the lower (abaxial)-leaf surface, or be confined near the tip, base or margins of the leaf blade. Moreover, the injured compound leaves often show a pattern of similar-aged tissue/leaflets being affected (e.g. opposite leaflets with injury at tip, base or margins). All ages of leaves potentially can be affected, but normally the injury is more pronounced on middle-aged compound leaves.

B) Methods

The regular injury assessment survey on tomatoes each year (1983-1990) was conducted during early to mid-July. Prior to 1985, aside from assessing the tomato cultivar trials at experimental stations, tomato plants were inspected in commercial fields and home or market gardens at 12 locations in 1983 and at 10 locations in 1984 (see Figure 1). Since 1985, the inspections on tomatoes in July have been confined to the cultivar trials at the Harrow, Ridgetown, Simcoe, Smithfield and Kemptville experimental stations (Figure 2). In August 1985, the tomato trials were re-examined at Harrow and Ridgetown to assess the injury at a more mature stage of plant growth.

Normally, at each location, one or two representative plants of each cultivar were inspected. Compound leaves on the main shoot(s) were inspected and the average injury (%) to each leaf was determined. The average injury to each plant was calculated using the formula A/B x C, where A = the number of injured leaves; B = the total number of examined leaves and C = the average injury to all affected leaves.

c) Results

Observations July 1983-1990

The results of the regular July surveys on tomatoes (1983-1990) are summarized in Tables 6, 7 & 10. Table 6 shows the percentage of observations in the none (0), trace (>0-1%), light (2-10%) and moderate (11-35%) injury categories and the corresponding total injury severity index score for each of the experimental stations each year. This table shows that most of the tomato plants examined each year exhibited either no injury or only trace injury overall to the foliage. There were only a few incidences of injury in the light and moderate categories. The highest total injury severity index scores varied among stations from year to year. This may, in part, reflect the non-continuous monitoring at Smithfield and Kemptville. The highest scores were obtained at Smithfield in 4 of 6 years when this station was monitored and in 2 of 3 years at Kemptville. The tomato plants/varieties which were found to be the most adversely injured over the past 8 years (1983-1990) at the experimental stations were FM 6203, H 2653, Jackpot, Ohio 7814, Ont 4240, Pik Red, Simcoe and Stokes Pak.

On commercial or garden plantings, only trace or very light injury was observed in 1983 and/or 1984 near Bloomfield, Clear Creek, Dresden, Harrow, Kettleby, Merlin, Oshawa, Port Stanley, Reeces Corners and Woodslee (Figure 1). Of these locations, the most severe injury (2-5%) was observed near Bloomfield and Merlin in 1984.

Table 10 and the accompanying bar graph show that the severity of ozone injury to tomatoes (including commercial/garden, plantings) across southern Ontario peaked in the late 1970's, was minimal in the mid 1980's and was increased slightly again in recent years (1987-1990). In most years, the severity of ozone injury to tomato plantings across southern Ontario was very light overall at the time of the surveys.

Observations August 1985

In August 1985, the injury at Ridgetown was found to have slightly increased from July on the varieties H 2653 and Jackpot. These cultivars exhibited light injury (5 %) in August. The injury to the cultivar trials at Harrow was unchanged from July and was trace (>0-1 %) on injured plants.

D: SURVEYS ON POTATO

a) Background

Potatoes have been inspected for foliar injury by ozone by Phytotoxicology staff on an annual basis since 1977. The regular survey on potatoes each year was conducted at the same time as the tomato survey in early to mid-July.

Ozone injury to potato foliage can occur on both upper and lower surfaces. The symptoms on the upper surface appear as blackened stipples or flecks which can coalesce and become bifacial. The symptoms on the undersurface appear as irregularly-sized, silver-grey lesions which also can become bifacial and coalesce as they increase in size and severity. The lower surface symptoms very closely resemble those which have been documented on tomato foliage. The foliar symptoms usually appear sometime between late June to mid-July when the plants have flowered and the tubers are developing. As the demands for photosynthetically-produced compounds at this time are at their peak the

potential for adverse yield effects is enhanced.

b) Methods

Prior to 1985, potato plants were examined for ozone symptoms in July at both experimental stations and commercial or garden locations. Commercial or garden plantings were inspected at 10 locations in both 1983 and 1984. Since 1985, the potato inspections each year have been confined primarily to the varietal trials at the Harrow, Simcoe, Cambridge, Kettleby and Kemptville experimental stations. Cultivar trilas were not inspected at Harrow in 1990 nor at Ridgetown from 1986 to 1990 because no cultivar trials were planted at either station. In 1990, the CDA potato trails at the University of Western Ontario experimental farm near London were inspected for the first time. These trials were located at Ridgetown prior to 1986 (see Figure 2). In addition, the potato trials were re-examined in mid-August at Cambridge, Simcoe and Kettleby in 1984 and 1985 and at Simcoe and Cambridge in 1986. In 1984, commercial plantings near Alliston and Thedford also were inspected in August.

The injury evaluation method was identical to the one used on tomato. All leaves were examined on the main vine(s) of one to two representative plants per variety and the average injury to each plant was calculated and expressed in percent.

c) Results

Observations July 1977-1990

The observations from the regular potato surveys in July each year (1977-1990) are summarized in Tables 8, 9 and 10. Table 8 shows the percentage of observations in each of the injury categories (trace, light etc.) in which injury was observed at the experimental stations during 1977 through 1990. With few exceptions, ozone injury to potatoes at all stations was either absent, trace or light in severity. The exceptions were 1986 at Ridgetown and 1989 at Harrow, where a few plants had moderate injury. The highest injury indices varied among stations from year to year. The Harrow station had the most frequent high index (3 of 5 years when observations were conducted). The highest injury index over all stations between 1983 and 1990 occurred in 1989, with the second highest value being recorded in 1990. At the experimental stations during the past 8 years, the most severe ozone injury was observed on the varieties Denali, Eramosa, Gold Rus, Jemseg, Norland, Rose Gold, Viking and Yukon gold. Of these potato cultivars, Norland is the most sensitive to ozone.

On commercial potato plantings, only trace or very light injury was observed in 1983 and/or 1984 near Alliston, Ballantrae, Blytheswood, Brampton, Burlington, Erieau, Kettleby, Leamington, Millbrook, Oshawa, Point Pelee, Port Stanley, and Thedford (Figure 1). The most severe injury, which was very light (2 %), was observed at Erieau and Burlington in 1983.

All plants affected each year were injured on the under surface of the leaves and only some plants exhibited blackish stipples on the upper surface.

Table 10 and the accompanying bar graph show the severity of ozone injury that was observed each year (1977-1990) on potato plantings overall (including commercial plantings) across southern Ontario. As with tomatoes, ozone injury to potato crops was most severe in the mid-1970's, was minimal in the mid-1980's and was increased slightly in recent years (1987-1990). However, all the annual (1977-1990) total injury index values shown in Table 10 were quite low and of light severity, including the highest score which was found in 1977 (15).

Observations August 1984 - 1986

At the three experimental stations (Cambridge, Simcoe and Kettleby) revisited in August during 1984 to 1986, each year the severity of ozone injury to the varietal trials was found to have increased overall from the July observations. The only exceptions were Cambridge and Kettleby in 1985. In 1985, no injury was observed at Kettleby. The most severe injury was observed at all stations in August of 1984. The varieties Denali, Norchip, Shepody and Yukon Gold at Cambridge or Simcoe were the most adversely affected (light to moderate injury, 3-16 %). All other varieties that were examined each year (1984-1986) in August at these stations exhibited only trace to very light injury (<1-5 %).

In 1984, the commercial plantings which were examined in August near Thedford displayed only trace injury. Those inspected in the Alliston area were injury free, as in July.

E: OTHER FIELD CROPS INSPECTED/INJURED 1983-1985

Several other field crops (primarily vegetables) also were inspected for ozone injury during the regular tomato and potato surveys from 1983 to 1985. Since 1985, the data obtained for crops, other than tomato, potato and white beans, is very limited.

In July of 1983 and 1984, vegetable crops were examined in marsh areas near Thedford, Point Pelee, Erieau, Wainfleet and Kettleby (Figure 1) as well as at several other locations across southern Ontario. One or more vegetable crops were examined at several of the locations shown on Figure 1. A total of 25 different crops (27 including potato and tomato) were inspected at marsh and garden sites in July during 1983 and 1984. Plantings of soybean, tobacco and cultivated grape also were inspected at a few locations each year in July. In 1984 and 1985, a few vegetable plantings (e.g. onion, lettuce) were examined in August. Also, in 1985, tobacco plants at Harrow were examined in July and August.

In July 1983, trace ozone injury was observed on foliage of the following vegetable/muck crops at the location(s) shown in parenthesis - snapbean (Harrow), celery (Erieau), Boston lettuce (Mount Albert), and cooking onion (Thedford). Also showing trace injury in July of 1983 were soybean plants at Harrow, Point Pelee, and Erieau and cultivated grape plants at Simcoe and Vineland.

In July 1984, injury was observed on spanish onion near Simcoe, green onion and radish at Kettleby and Boston lettuce near Mount Albert. In all of these cases, the injury was either trace or very light in severity (<1-2 %). Moreover, in July 1985, very light injury (<5 %) was observed on onion plants at Harrow.

In addition, Bel W3 tobacco plants at the Cambridge and Harrow experimental stations were injured in July 1983 and 1984, as were Bel W3 plants at the Simcoe station in 1983 and at Delhi in 1984. The injury to tobacco at these locations was light (5-10 %) in both years. In 1985, Bel W3 tobacco plants at Harrow had light injury in July (10 %) and moderate injury in August (15 %). Bel W3 tobacco is highly sensitive to ozone and is used as a bioindicator in experimental plots. Ozone injury was either absent or unconfirmed on the other crops which were examined in July and/or August from 1983 to 1986. This corresponds with the period of very low incidence of injury to tomato and potato (Table 10)

F: SPECIAL OZONE INJURY SURVEY JUNE 1983

During late June 1983, a special ozone survey was conducted because of considerable media concern about the elevated ambient ozone levels which occurred earlier in June. During this survey, a total of 365 observations overall were made on 28 different crops at 54 locations across southern Ontario.

Potato and tomato crops were examined at most locations. Bel W3 tobacco plants (ozone bioindicators) also were inspected at the Harrow, Simcoe and Delhi experimental stations. Several other crops also were examined - barley, beets, beans (white, soy, snap), carrots, celery, cucurbits (cucumber, squash), corn (field, sweet), eggplant, grape (wild, cultivated), lettuce (Boston, Romaine, head), oats, onion (cooking, Dutch sets, green, Spanish), peanuts, peas, radish, spinach and tobacco (flue, burley types). Vegetable crops such as celery, lettuce, onion and spinach were primarily examined in major muck crop areas - Pt. Pelee, Erieau, Thedford and Kettleby (see Figure 1).

Foliar inspections revealed that ozone injury on most affected potato and tomato plantings was only trace (<1 %) in severity. The most severe overall plant injury was observed on tomatoes (5 %) at Harrow. At the Harrow experimental station, ozone injury also was detected on Boston lettuce (overall 5 %) and Bel W3 tobacco (overall <2 %). Bel W3 tobacco plants at Simcoe also manifested foliage with typical ozone injury (overall <3 %). In addition, slight injury (<1 %) was observed on radish at Pt. Pelee and on Dutch set onions at Erieau. Ozone injury was not observed on the other crops that were examined.

In summary, in spite of the high ozone episodes in mid June, ozone injury to sensitive crops across S. Ontario was found to be extremely light in the following weeks.

However, in 1983, weather conditions were generally cool and wet in April and May, which delayed planting and subsequent crop development in many areas. During June, unusually low rainfall was recorded at several locations across Ontario. Even by late June, many crops were still immature.

Immature plants usually are not as sensitive to ozone injury as they would be around flowering time. Moisture stress conditions also can reduce plant sensitivity to ozone. Therefore, it is suspected that late planting coupled with plant immaturity and possibly low rainfall in June contributed to the low degree of ozone injury that was observed on sensitive crops across southern Ontario in late June.

If crops had been planted earlier and if weather conditions had been more ideal for plant growth during the spring of 1983, it is likely ozone injury would have been more severe.

G: RESULTS OF HISTOLOGICAL EXAMINATIONS

Each year (1983-1990), injured foliage was collected during the surveys and submitted for histological examination in the Phytotoxicology Laboratory. From 1983 to 1990, a total of 55 foliage samples were collected. The cellular injury pattern observed on 45 samples (82 % of total) was confirmed to be typical of ozone (Table 12).

H: AMBIENT OZONE CONCENTRATIONS

Summarized in attached Tables 13 and 14 are the ambient ozone levels which were recorded in southern Ontario just prior to the surveys on white beans, tomatoes and potatoes.

As shown in Table 13, during July and/or August each year (1983-1990) in the primary white bean production area, ambient ozone levels were, at times, at or above the MOE 80 ppb hourly criterion and were potentially injurious to sensitive crops. In most years, this criterion was exceeded most often at Parkhill, where the worst years were 1984, 1987 and 1990. These also were the years white bean plantings in the nearby Centralia-Kippen area were found to have the most severe ozone injury in August from 1983 to 1990 (see Table 3). However, over the four common years (1983, 1985, 1986 & 1990) ozone data is shown for the 4 stations in Table 13, Windsor (Harrow) was found to have the highest total number of exceedances of the 80 ppb criterion compared to the other 3 sites. The 3 sites also showing ozone data for 1984 and 1987 (Parkhill, Merlin and London) further revealed that the worst years overall, during 1983 to 1990, were still 1984, 1987 and 1990.

Table 14 summarizes the ambient ozone levels which were recorded in June and July in the vicinity of the 7 experimental stations where tomato and/or potato plants were inspected for ozone injury in July from 1983 to 1990. This table shows that each year, in most areas, potentially injurious ozone levels were recorded prior to the tomato/potato survey. The highest ozone levels usually were monitored at either Simcoe or Merlin. The worst years for ozone, based on the overall number of exceedances of the MOE criterion of 80 ppb, were 1988, 1983 and 1989 in this order. However, during these years, the severity of ozone injury to tomato and potato plantings across southern Ontario was found to be very light overall, suggesting that the plants were not highly sensitive at the time of the ozone episodes. Plant sensitivity to ozone and injury severity are influenced by several factors (e.g. air temperature, humidity, sunlight, soil moisture, soil nutrient levels, crop, variety and stage of growth). During the 1988 growing season, weather conditions were unusually hot and dry. Hot, droughty conditions can reduce the sensitivity of plants to ozone and these conditions may have contributed to the very light injury to tomatoes/potatoes in 1988.

I: SUMMARY

Every year (1983-1990), during the regular July or August surveys, ozone injury was observed on the foliage of sensitive white bean, tomato and potato plantings at several locations across southern Ontario. The most severe injury generally was observed in August on white beans, which is one of the most sensitive crops to ozone. Injury ranging from trace to severe was observed on sensitive white bean plantings each year. The annual injury index values fell in the severe category in 1984 and 1990 (as in 1976) and were increased compared to other years. In most other years since the white bean survey began, the overall severity of ozone injury to the white bean plantings which were inspected, was found to be light or moderate.

Ozone injury to tomato and potato plantings also was found to be slightly increased overall in recent years (1987, 1989 and/or 1990). However, from 1983 to 1990, the severity of acute ozone injury to tomato and potato plantings in July across southern Ontario was found each year to be very light overall.

The broader surveys/observations in July of 1983 and 1984, together with the histological results, also confirmed the presence of ozone injury on the foliage of snapbean, soybean, celery, cultivated grape, Boston lettuce, onion, radish and tobacco at some sites. On these crops, the injury severity in most cases was trace, and only at a few locations was more adverse injury observed. During the special ozone survey in June of 1983, the severity of ozone injury to field crops across southern Ontario also was found to be very light overall.

In the years (1984-1986) during which tomato, potato and/or Bel W3 tobacco plants were examined in both July and August, the injury was generally more severe in August. The most severe injury observed during these years was on sensitive potato and tobacco plants, and was light or moderate in severity.

Every year (1983-1990), ambient ozone levels above the MOE criterion of 80 ppb were recorded at several locations during June through August. The assessment surveys confirm that the ozone concentrations which occurred during the growing season each year were injurious to sensitive field crops across southern Ontario.

Literature Cited

Summary of Foliar Assessment Surveys for Oxidant Injury to Field Crops in Southern Ontario: 1971-1982 (Report ARB-89-83-Phyto)

Table 1: Annual Severity of Ozone Injury to White Beans at Each of the Experimental Sites Visited During August from 1983 to 1990

Location Yr. (Day)	Total Obs.	Percentage (%) Observations in Each Injury Category: None (0)*	Trace (1)*	Light (2-3)*	Moderate (4)*	Severe (5)*	Severity Index Values** Trace (5)	Light (25)	Moderate (50)	Severe (100)	Total Index Score**** (Out of 100)
							- Weighting Factor -				
Harrow											
1983 (17)	4	0	0	50	25	25	0	12.5	12.5	25	50
1985 (28)	4	0	25	50	25	0	1.3	12.5	12.5	0	26
1986 (22)	14	0	0	29	50	21	0	7.3	25	21	53
1990 (27)	15	0	0	7	13	80	0	1.8	6.5	80	88
Ridgetown											
1983 (17)	9	11	22	44	22	0	1.1	11	11	0	23
1984 (30)	11	0	0	36	27	36	0	9	13.5	36	59
1985 (28)	21	0	19	57	5	19	1	14.3	2.5	19	37
1986 (22)	64	17	44	34	5	0	2.2	8.5	2.5	0	13
1987 (20)	50	0	2	36	46	16	0.1	9	23	16	48
1990 (28)	34	0	0	6	41	53	0	1.5	20.5	53	75
Centralia/Huron Park											
1983 (17)	5	20	0	60	20	0	0	15	10	0	25
1985 (28)	18	0	0	39	50	11	0	9.8	25	11	46
1986 (25)	36	0	17	53	22	8	0.9	13.3	11	8	33
1987 (20)	42	0	26	50	17	7	1.3	12.5	8.5	7	29
1990 (28)	34	0	6	18	26	50	0.3	4.5	13	50	68
Kippen* **											
1984 (30)	9	0	0	23	44	33	0	5.5	22	33	61
1986 (25)	35	17	63	20	0	0	3.2	5	0	0	8
1987 (20)	41	0	2	32	49	17	0.1	8	24.5	17	50
Brussels* **											
1985 (28)	18	44	28	22	6	0	1.4	5.5	3	0	10
1986 (25)	37	21	30	46	3	0	1.5	11.5	1.5	0	15
1987 (20)	42	0	12	24	55	9	0.6	6	27.5	9	43
Elora											
1983 (18)	3	0	34	33	33	0	1.7	8.3	16.5	0	27
1984 (30)	6	0	0	0	17	83	0	0	8.5	83	92
1986 (25)	5	0	0	40	60	0	0	10	30	0	40
1987 (20)	37	0	24	57	19	0	1.2	14.3	9.5	0	25
1990 (27)	39	5	28	31	15	21	1.4	7.8	7.5	21	38

* Corresponding numerical injury rating utilized from 1975-1990

** Calculated by multiplying percentage value (decimal) by assigned wieghting factor for each injury category and adding the 4 values for a Total Index Score (Maximum 100) (i.e. 15% in trace = .15 x 5 = .75)

*** OMAF variety trial plot. All other locations were experimental stations. **** Values rounded off to nearest whole number

Table 2: Overall Annual Severity of Bronzing Injury to White Beans in Southern Ontario from 1971 to 1990

Year	Total Obs.	Percentage (%) Observations in Each Injury Category: None (0)*	Trace (1)*	Light (2-3)*	Moderate (4)*	Severe (5-6)*	Severity Index Values** Trace (5)	Light - Weighting Factor - (25)	Moderate (50)	Severe (100)	Total Index Score*** (Out of 100)
1971	21	71	5	14	10	0	0.3	3.5	5	0	9
1972	43	62	19	9	5	5	1.0	2.3	2.5	5	11
1973	50	4	8	32	42	14	0.4	8.0	21	14	43
1974	33	6	15	37	33	9	0.8	9.3	16.5	9	36
1975	39	8	8	48	18	18	0.4	12	9	18	39
1976	54	0	7	19	30	44	0.4	4.8	15	44	64
1977	28	4	14	42	36	4	0.7	10.5	18	4	33
1978	11	9	18	46	27	0	0.9	11.5	13.5	0	26
1979	13	0	40	30	30	0	0.2	7.5	15	0	23
1980	21	0	14	38	33	14	0.7	9.5	16.5	14	41
1981	17	0	12	65	23	0	0.6	16.3	11.5	0	28
1982	48	2	23	44	27	4	1.2	11	13.5	4	30
1983	21	14	14	48	19	5	0.7	12	9.5	5	27
1984	36	3	6	19	25	47	0.3	4.8	12.5	47	65
1985	61	13	16	41	20	10	0.8	10.3	10	10	31
1986	191	13	35	37	12	3	1.8	9.3	5.5	3	20
1987	212	0	13	39	38	10	0.7	9.8	19	10	40
1990	122	2	11	17	25	45	0.6	4.3	12.5	45	62

* Corresponding numerical injury rating utilized from 1975-90

** Calculated by multiplying percentage value (decimal) by assigned weighting factor for each injury category and adding the 4 values for a Total Index Score (maximum of 100)(i.e. 15% in trace = .15 x 5 = .75)

*** Values have been rounded off to neareast whole number

Note: Surveys were not conducted in 1988 and 1989

Table 3: Total Injury Severity Index to White Beans for Each Location from 1983 to 1990

Year	Harrow	Ridgetown	Centralia /Huron Park	Kippen	Brussels	Elora
1983	50	23	25	-	-	26
1984	-	59	-	61	-	92
1985	26	37	46	-	10	-
1986	53	13	26	8	15	40
1987	-	40	29	50	44	25
1990	88	75	68	-	-	38

Note: OMAF's experimental farm at Centralia was move to nearby Huron Park in 1987

Table 4: Comparison of Annual Ozone Injury Severity Index to White Beans in Southern Ontario from 1971 to 1990

Year	Total Index	Annual Severity Category
1984	65	
1976	64	Severe (> 50)
1990	62	
1973	43	
1980	41	
1987	40	Moderate (36-50)
1975	39	
1974	36	
1977	33	
1985	31	
1982	30	
1981	28	Light (20-35)
1983	27	
1978	26	
1979	23	
1986	20	
1972	11	
1971	9	Trace (< 20)

Table 5: Comparison of Injury Severity to White Beans Between Locations from 1985 - 1990

	Year/Location			
	1885	1986	1987	1990
Duncan's Multiple Range Test	Centralia a Ridgetown a Harrow a Brussels b	Harrow a Centralia a Brussels b Kippen b,c Ridgetown c	Kippen a Ridgetown a Brussels a,b Elora a,b Huron Park b	Harrow a Ridgetown a Huron Park a Elora b
F Value	13.61**	15.14**	2.97*	9.87**

* Significant ($p < 0.05$)
** Highly significant ($p < 0.01$)

Note: Injury ratings at locations followed by the same letter were not significantly different

Table 6: Annual Severity of Ozone Injury to Tomatoes at Experimental Stations Visited During July from 1983 to 1990

Location/ Yr.(day)	Total Obs.	Percentage (%) Observations in Each Catergory: None (0)	Trace (>0-1%)	Light (2-10%)	Moderate (11-35%)	Severity Index Values* Trace - Weighting Factor - (5)	Light (25)	Moderate (50)	Total Index Score** (Out of 100)
Harrow									
1983 (14)	6	83	17	-	-	0.9	-	-	1
1984 (10)	1	100	-	-	-	-	-	-	0
1985 (3)	31	94	6	-	-	0.3	-	-	1
1986 (7)	46	100	-	-	-	-	-	-	0
1987 (7)	14	0	100	-	-	5	-	-	5
1988 (6)	19	53	37	10	-	1.9	2.5	-	4
1989 (12)	26	19	81	-	-	4.1	-	-	4
1990 (11)	29	38	62	-	-	3	-	-	3
Ridgetown									
1983 (19)	12	75	25	-	-	1.3	-	-	1
1984 (10)	13	92	8	-	-	0.4	-	-	1
1985 (3)	19	10	74	16	-	3.7	4	-	8
1986 (7)	23	39	52	9	-	2.6	2.3	-	5
1987 (7)	19	26	68	0	5	3.4	0	2.5	6
1988 (6)	24	37	63	-	-	3.2	-	-	3
1989 (12)	26	23	73	4	-	3.7	1	-	5
1990 (11)	34	38	53	9	-	2.7	2.3	-	5
Simcoe									
1983 (20)	7	57	43	-	-	2.2	-	-	2
1984 (10)	8	100	-	-	-	-	-	-	0
1985 (2)	35	89	11	-	-	0.6	-	-	1
1986 (8)	54	100	-	-	-	-	-	-	0
1987 (6)	6	50	50	-	-	2.5	-	-	3
1988 (5)	28	79	14	7	-	0.7	1.8	-	3
1989 (11)	24	62	38	-	-	1.9	-	-	2
1990 (10)	27	59	41	-	-	2.1	-	-	2
Smithfield									
1984 (13)	14	86	4	-	-	0.7	-	-	1
1985 (4)	26	92	8	-	-	0.4	-	-	1
1986 (9)	18	22	67	11	-	3.4	2.8	-	6
1987 (8)	20	0	90	10	-	4.5	2.5	-	7
1989 (17)	13	8	92	0	-	4.6	-	-	5
1990 (16)	20	0	85	15	-	4.3	3.8	-	8
Kemptville									
1984 (16)	11	55	36	9	-	1.8	2.3	-	4
1985 (4)	20	55	40	5	-	2	1.3	-	3
1986 (9)	17	23	65	12	-	3.3	3	-	6

* Calculated by multiplying percentage value (decimal) by assigned weighting factor for each injury category (i.e. 15% in trace = 0.15 x 5 = 0.75). Total Index Score (maximum 100) is the sum of the severity index values

** Values rounded off to nearest whole number

Table 7: Comparison of Annual Ozone Injury Severity Index to Tomatoes at Experimental Stations Visited During July from 1983 to 1990

Location	Injury Severity Index (Maximum 100)							
	1983	1984	1985	1986	1987	1988	1989	1990
Harrow	1	0	1	0	5	4	4	3
Ridgetown	1	1	8	5	6	3	5	5
Simcoe	2	0	1	0	3	3	2	2
Smithfield	-	1	1	6	7	-	5	8
Kemptville	-	4	3	6	-	-	-	-
Overall*	1	2	2	2	6	3	4	4

* Experimental farms plus other locations (e.g. commercial sites in 1983/84)

Table 8: Annual Severity of Ozone Injury to Potatoes at Experimental Stations Visited During July from 1983 to 1990

Location Yr. (Day)	Total Obs.	Percentage (%) Observations in Each Category: None (0)	Trace (>0-1%)	Light (2-10%)	Moderate (11-35%)	Severity Index Value* Trace - Weighting Factor - (5)	Light (25)	Moderate (50)	Index Score (100)
Harrow									
1985 (3)	10	70	30	-	-	1.5	-	-	2
1986 (7)	16	100	-	-	-	-	-	-	0
1987 (7)	12	0	58	42	-	2.9	10.5	-	13
1988 (6)	14	71	29	-	-	1.5	-	-	2
1989 (12)	8	0	38	50	12	1.9	12.5	6	20
London									
1990 (12)	20	0	85	15	-	4.3	3.8	-	8
Ridgetown									
1983 (19)	8	38	38	25	-	1.9	6.3	-	8
1984 (10)	11	82	18	-	-	0.9	-	-	1
1985 (3)	28	89	7	4	-	0.4	1	-	1
1986 (7)	22	26	64	5	5	3.2	1.3	2.5	7
Simcoe									
1983 (20)	11	46	45	9	-	2.3	2.3	-	5
1984 (10)	11	64	18	18	-	0.9	4.5	-	5
1985 (2)	21	62	38	-	-	1.9	-	-	2
1986 (8)	46	52	44	4	-	2.2	1	-	3
1987 (6)	25	20	80	-	-	4	-	-	4
1988 (5)	40	85	15	-	-	0.8	-	-	1
1989 (11)	23	0	61	39	-	3.1	9.8	-	13
1990 (10)	21	48	52	-	-	2.6	-	-	3
Cambridge									
1983 (20)	13	70	15	15	-	0.8	3.8	-	5
1984 (11)	9	89	11	-	-	-	0.6	-	1
1985 (2)	21	0	100	-	-	-	-	-	0
1986 (8)	28	86	14	-	-	0.7	-	-	1
1987 (6)	22	100	-	-	-	-	-	-	0
1988 (6)	16	63	37	-	-	1.9	-	-	2
1989 (13)	26	38	62	-	-	3.1	-	-	3
1990 (12)	26	31	58	11	-	2.9	2.8	-	6
Kettleby									
1983 (18)	6	50	50	-	-	2.5	-	-	3
1984 (12)	8	75	25	-	-	1.3	-	-	1
1985 (5)	10	100	-	-	-	-	-	-	0
1986 (9)	14	86	14	-	-	0.7	-	-	1
1987 (9)	10	100	-	-	-	-	-	-	0
1988 (7)	20	25	75	-	-	3.8	-	-	4
1989 (13)	18	50	50	-	-	2.5	-	-	3
1990 (9)	10	40	60	-	-	3	-	-	3
Kemptville									
1984 (16)	6	50	50	-	-	2.5	-	-	3
1985 (4)	16	88	12	-	-	0.6	-	-	1
1986 (9)	19	53	47	-	-	2.4	-	-	2
1987 (8)	20	100	-	-	-	-	-	-	0
1989 (18)	12	0	83	17	-	4.2	4.3	-	9
1990 (16)	20	5	80	15	-	4	3.8	-	8

* Calculated by multiplying percentage value (decimal) by assigned weighting factor for each injury category (i.e. 15% in trace = 0.15 x 5 = 0.75). Total Index Score (maximum 100) is the sum of the 3 severity index values

Table 9: Comparison of Annual Ozone Injury Severity Index to Potatoes at Experimental Stations Visited During July - 1983 to 1990

Location	Injury Severity Index (Maximum 100)							
	1983	1984	1985	1986	1987	1988	1989	1990
Harrow	-	-	2	0	13	2	20	-
Ridgetown	8	1	1	7	-	-	-	-
London	-	-	-	-	-	-	-	8
Simcoe	5	5	2	3	4	1	13	3
Cambridge	5	1	0	1	0	2	3	6
Kettleby	3	1	0	1	0	4	3	3
Kemptville	-	3	1	2	0	-	9	8
Overall*	4	2	1	3	3	2	8	6

* Experimental farms plus other locations (e.g. commercial sites in 1983/84)

Table 10: Severity of Ozone Injury Detected on Tomato and Potato Plantings Overall Each Year Since 1974

Year	Annual Total Injury Severity Index Score* (Maximum 100)	
	Tomato	Potato
1974	5	-
1975	4	-
1976	11	-
1977	18	15
1978	6	9
1979	9	8
1980	7	5
1981	2	2
1982	3	10
1983	1	4
1984	2	2
1985	2	1
1986	2	3
1987	6	3
1988	3	2
1989	4	8
1990	4	6

* Based on all sites visited each year

Note. Surveys on tomato were conducted in late June during 1974 to 1979 and during early to mid July from 1980 to 1990. Surveys on potato commenced in 1977

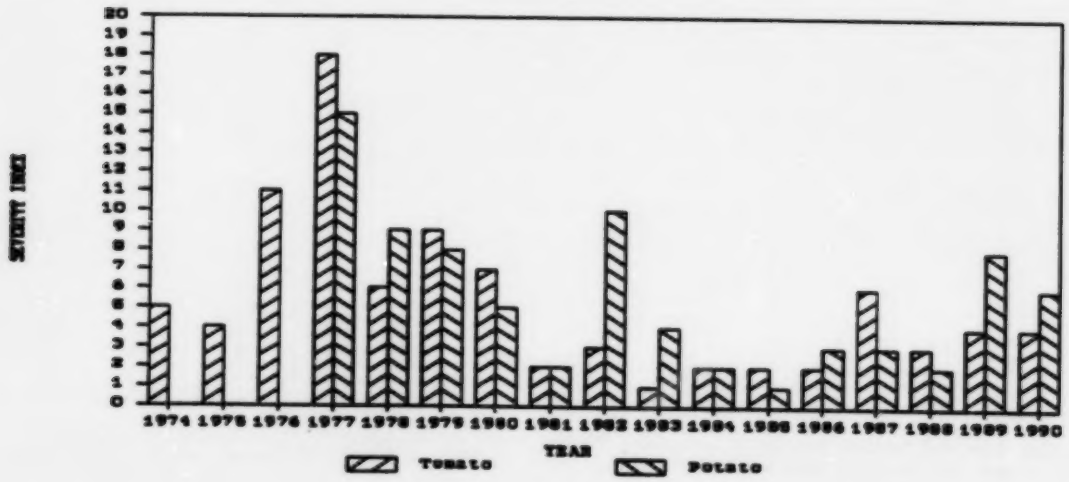


Table 11: Crops and Total Number of Observations and Varieties Examined Each Year from 1983 through 1990

Crop	Year	Total Visual Examinations	No. Different Crop Varieties Inspected
White beans (August)	1983	21	8
	1984	36	11
	1985	61	21
	1986	191	46
	1987	212	42
	1990	122	46
	Note: In 1988 and 1989 No Survey		
Tomato	1983*	225	26
	1984	89	47
	1985*	155	50
	1986	158	54
	1987	59	17
	1988	71	22
	1989	89	41
	1990	110	36
Potato	1983*	203	18
	1984*	97	17
	1985*	128	25
	1986*	129	25
	1987	90	14
	1988	92	18
	1989	91	20
	1990	103	17
			No. Different Crops
Other Crops**	1983*	605	28
	1984	70	26
	1985	12	3

* Including June or August Observations

** Primarily Vegetable crops

Table 12: Foliage Samples Collected for Histological Examination during July and/or August from 1983 through 1990

Year	Location (Fig. 1 & 2)	Crop	Sample No.	Injury Description	Histological Results	
					Ozone	Atypical or unconfirmed
1983	Harrow	soybean	009	upper surface stippling	X	
	Harrow	tobacco	010	upper surface flecks/stippling	X	
	Pt. Pelee	soybean	011	upper surface stippling	X	
	Erieau	onion	012	whitish flecks		X
	Erieau	celery	013	tan flecks	X	
	Erieau	celery	014	flecking		X
	Erieau	potato	015	stippling & bifacial lesions	X	
	Delhi	peanut	016	upper surface brown flecks	X	
	Mt. Albert	B. lettuce	017	upper surface stippling	X	
	Alliston	potato	779	under surface lesions	X	
	Alliston	potato	780	under surface grey lesions	X	
	Ridgetown	potato	781	under surface bronze lesions	X	
	Ridgetown	potato	782	under surface pin head lesions	X	
	Thedford	onion	783	whitish flecks	X	
	Elora	w. bean	1090	upper surface brown stipples	X	
1984	Simcoe	potato	078	under surface grey lesions	X	
	Mt. Albert	B. lettuce	079	upper surface stippling	X	
	Harrow	potato	857	under surface lesions	X	
	Merlin	tomato	858	under surface lesions	X	
	Kettleby	potato	860	under surface lesions	X	
	Kettleby	onion	861	whitish flecks	X	
	Kettleby	radish	862	upper surface glazing	X	
	Alliston	potato	863	bifacial lesions	X	
	Smithfield	tomato	864	under surface lesions	X	
	Kemptville	potato	865	under surface lesions	X	
	Kemptville	tomato	866	under surface lesions	X	
1985	Ridgetown	potato	967	under surface lesions	X	
	Kemptville	potato	968	under surface lesions	X	
	Kemptville	tomato	969	under surface bronze glazing	X	
	Smithfield	tomato	970	under surface bronze glazing	X	
	Ridgetown	tomato	1183	bifacial lesions	X	
	Simcoe	potato	177	dark bifacial lesions	X	(+ disease)
	Simcoe	potato	178	dark bifacial lesions	X	(+ disease)
1986	Ridgetown	tomato	757	under surface bronze glazing	X	
	Ridgetown	tomato	758	under surface lesions	X	
	Kemptville	tomato	759	under surface copper glaze	X	
	Kettleby	potato	760	under surface lesions	X	
	Smithfield	tomato	761	under surface copper glaze	X	
	Smithfield	tomato	762	under surface copper glaze	X	
	Smithfield	tomato	763	under surface grey-bronze lesions	X	
1987	Simcoe	potato	1653	under surface grey lesions		X
	Harrow	potato	1654	under surface lesions	X	
	Ridgetown	tomato	1655	under surface bronze lesions	X	
	Smithfield	tomato	1656	under surface bronze glazing		X
	Smithfield	tomato	1657	under surface copper lesions	X	
1988	Simcoe	potato	1380	under surface copper lesions	X	
	Harrow	tomato	1381	under surface copper lesions	X	
	Harrow	potato	1382	under surface copper glaze	X	
	Cambridge	potato	1383	under surface copper lesions		X
	Cambridge	potato	1384	under surface copper lesions		X
1989	Cambridge	potato	1550	under surface dark bronze lesions	X	
1990	Kettleby	potato	1563	upper surface dark bronzed areas		X
	Kettleby	potato	1564	bifacial copper lesions		X
	Simcoe	potato	1565	upper surface dark bronzed areas		X
	Simcoe	potato	1566	upper surface dark bronzed areas		X

Table 13: Summary of Ambient Ozone Levels Recorded in the Primary White Bean Production Area Prior to the Assessment Survey in August from 1983 to 1990

Air Monitor Location/ Year & Date of Survey	Ozone Concentration (ppb)*						
	July			August**			Tot. hrs.
	Mean	No. hrs. 80 ppb or more	Max. conc. 1 hr.	Mean	No. hrs. 80 ppb or more	Max. conc. 1 hr.	80 ppb or more
Windsor (Harrow)* **							
1983 Aug. 17	49	21	123	47	14	110	35
1985 Aug. 28	52	16	98	42	9	114	25
1986 Aug. 22	42	3	94	41	1	82	4
1990 Aug. 27	40	11	97	38	4	92	15
Parkhill (Centralia/Huron Park/Kippen/Brussels)* **							
1983 Aug. 17	42	1	80	49	7	96	8
1984 Aug. 30	49	21	125	46	10	97	31
1985 Aug. 28	35	2	100	37	0	76	2
1986 Aug. 25	46	16	103	33	0	73	16
1987 Aug. 20	50	20	121	46	15	113	35
1990 Aug. 28	43	19	110	43	8	95	27
Merlin (Ridgetown)* **							
1983 Aug. 17	46	18	121	35	0	66	18
1984 Aug. 30	40	0	79	33	0	70	0
1985 Aug. 28	31	0	77	26	0	66	0
1986 Aug. 22	34	0	76	missing data most days			
1987 Aug. 20	50	16	115	46	6	103	22
1990 Aug. 28	42	13	92	41	7	104	20
London**							
1983 Aug. 17	47	5	122	47	0	79	5
1984 Aug. 30	40	1	81	40	1	81	2
1985 Aug. 28	43	10	104	39	3	90	13
1986 Aug. 22	38	1	82	42	0	79	1
1987 Aug. 20	45	1	81	39	0	79	1
1990 Aug. 28	41	6	109	40	7	93	13

* Summary is based on a 7 hour day (900 - 1600 hours EST)
** For period ending on the day preceding the survey date.
*** Location in parenthesis represents experimental station and/or variety trial plot closest to air monitor
**** Survey dates correspond to those for Ridgetown

Note: The air monitoring data (e.g. Windsor) is summarized only for years surveys were conducted

Table 14: Summary of Ambient Ozone Concentrations Recorded Across Southern Ontario Prior to the Tomato and Potato Surveys in July from 1983 to 1990

Air Monitor Location/ Year & Date of Survey	Ozone Concentration (ppb)*						
	June			July**			
	Mean	No. hrs. 80 ppb or more	Max. conc. 1 hr.	Mean	No. hrs. 80 ppb or more	Max. conc. 1 hr.	Tot. Hrs. 80 ppb or more
Windsor (Harrow)* **							
1983 July 14	48	29	106	49	6	123	35
1984 July 10	43	0	78	52	9	90	9
1985 July 3	43	7	105	60	1	84	8
1986 July 7	40	9	102	48	3	94	12
1987 July 7	42	9	105	35	0	57	9
1988 July 6	49	26	98	65	13	122	39
1989 July 12	41	9	136	61	9	119	18
1990 July 11	30	4	102	44	2	97	6
Merlin (Ridgetown)* **							
1983 July 19	48	18	103	53	12	121	30
1984 July 10	37	2	87	32	0	67	2
1985 July 3	30	1	81	35	0	52	1
1986 July 7	33	2	82	43	0	69	2
1987 July 7	53	11	126	37	0	61	11
1988 July 6	69	58	123	60	11	101	69
1989 July 12	49	14	95	65	20	108	34
1990 July 11	44	7	90	46	7	92	14
Simcoe (Simcoe)* **							
1983 July 20	66	55	123	53	8	104	63
1984 July 10	64	44	115	49	3	110	47
1985 July 2	50	5	108	66	0	68	5
1986 July 8	48	12	100	52	3	82	15
1987 July 6	57	24	117	43	0	65	24
1988 July 5	58	45	124	52	7	94	52
1989 July 11	48	7	93	53	5	86	12
1990 July 10	46	5	93	45	5	96	10
Kitchener (Cambridge)* **							
1983 July 20	47	26	108	43	0	77	26
1984 July 11	37	0	76	35	0	74	0
1985 July 2	33	0	77	52	0	63	0
1986 July 8	35	9	110	56	5	87	14
1987 July 6	33	2	88	21	0	44	2
1988 July 6	41	30	112	38	1	109	31
1989 July 13	34	4	93	43	2	81	6
1990 July 12	39	6	93	42	1	80	7
Stouffville (Kettleby)* **							
1983 July 18	41	6	115	36	0	64	6
1984 July 12	33	0	71	35	0	70	0
1985 July 5	37	1	80	56	1	80	2
1986 July 9	37	3	95	41	0	79	3
1987 July 9	39	2	87	48	0	76	2
1988 July 7	44	16	93	62	10	161	26
1989 July 13	46	12	99	64	26	119	38
1990 July 9	39	3	96	39	0	68	3

Continued .....

Table 14 Cont'd: Ambient Ozone Concentrations Recorded Across Southern Ontario Prior to the Tomato and Potato Surveys in July from 1983 to 1990

Air Monitor Location/ Year & Date of Survey	Ozone Concentration (ppb)* June Mean	June No. hrs. 80 ppb or more	June Max. conc. 1 hr.	July** Mean	July No. hrs. 80 ppb or more	July Max conc. 1 hr.	Tot. hrs. 80 ppb or more
Peterborough (Smithfield)* **							
1984 July 13	27	0	79	21	0	76	0
1985 July 4	33	1	86	41	0	59	1
1986 July 9	26	1	86	33	2	87	3
1987 July 8	34	3	86	32	0	55	3
1989 July 17	35	3	89	47	9	96	12
1990 July 16	35	4	88	28	0	62	4
Ottawa (Kemptville)* **							
1984 July 16	31	0	65	32	0	79	0
1985 July 4	30	0	69	49	0	66	0
1986 July 9	29	0	71	28	0	73	0
1987 July 8	29	0	60	31	0	56	0
1989 July 18	30	0	66	42	3	93	3
1990 July 16	38	2	85	65	9	116	11

* Summary is based on a 7 hour day (900-1600 hours EST)
** For period ending on the day preceding the survey date
*** Experimental station closest to air monitor

Note: The air monitoring data is summarized only for years surveys were conducted

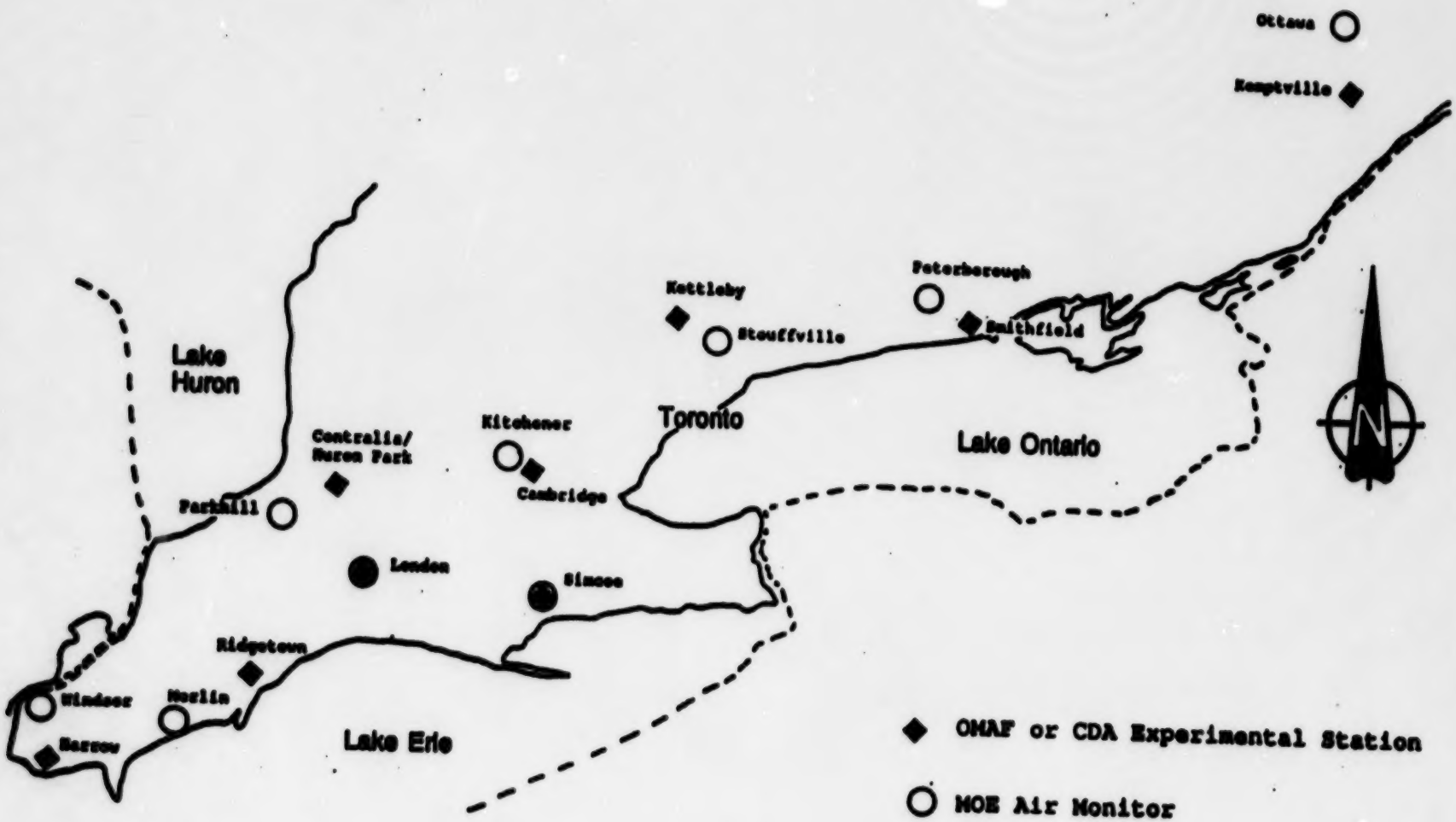
Figure 1: General Locations Field Crops were Inspected in July and/or August during 1983 to 1990

Area (Site No.) Crop(s)*
Alliston (38) W, P
Atwood (20) W
Bellantrae (42) P
Bloomfield (50) T
Blytheswood (3) T, P
Bowmanville (47) T, O
Brampton (35) P
Brussels (19) W
Burlington (34) T, P, O
Cambridge (29) W, P, T,
Centralia/Huron Pk. (16)
Cedar Springs (8) P, O
Clear Creek (25) T
Cookstown (39) P, O
Courtice (45) T, O
Darlington (46) T, O
Delhi (27) O
Dresden (11) T, O
Elora (30) W
Erieau (9) P, O
Exeter (17) W
Harrow (2) T, P, O
Kemptville (52) T, P
Kerwood (13) W
Kettleby (37) T, P, O
Kippen (18) W

Area (Site No.) Crop(s)*
Leamington (4) P, T, O
London (23) P
Markham (40) T, O
Merlin (7) T
Millbrook (48) P
Mt. Albert (43) T, O
Oshawa (44) P
Parkhill (15) W
Pickering (41) T
Point Pelee (5) P, O
Port Alma (6) T
Port Stanley (24) T, P, O
Reecos Corners (12) T, O
Ridgetown (10) W, T, P, O
Saint Davids (32) T
Saint Williams (26) T, O
Simcoe (28) T, P, O
Smithfield (49) T
Teviotdale (21) W
Thedford (14) P, O
Vineland (33) T, O
Wainfleet (31) T, O
Wallacetown (22) T
West Lake (51) T
Woodbridge (36) O
Woodslee (1) W, T, O

* W White bean
T Tomato
P Potato
O Other Crops

Figure 2: Experimental Stations and Air Monitoring Locations Cited in Report



MAPS
NOT
FILMED

CARTES
OMISES